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# Trends in expectancy for success and value beliefs at the secondary-tertiary transition into STEM fields

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*The elevated dropout rates in degree programs in science, technology, engineering, and mathematics (STEM) are in apparent contrast to the high mathematical self-concept prevalent among incoming students in these fields. This suggests that the attitudes and beliefs of students in STEM fields are challenged at the secondary-tertiary transition. This study expands research on expectancy and value beliefs in the context of schools to higher education. A longitudinal questionnaire study was conducted among beginning students in STEM fields (N = 428) to examine the development of their expectancy for success and value beliefs related to mathematics in the course of the first two months at university. A consistent decrease is observed in all measured aspects of expectancy and value beliefs. Significant differences depending on gender are seen in the developments of expectancy for success and several value beliefs, all in favour of male students.*

*Keywords: Expectancy-value theory, gender differences, secondary-tertiary transition, undergraduate students.*

## Introduction

Many studies have observed a steady decrease in the motivation to learn mathematics in the course of children's and adolescents' schooling (e. g., Lazarides et al., 2022; Schweder & Raufelder, 2022). Contrary to this overall trend, students who enter undergraduate programs in STEM fields (science, technology, engineering, mathematics) typically hold a high mathematics self-concept when graduating upper secondary school (Di Martino et al., 2022). Yet, bachelor programs in STEM fields have some of the highest dropout rates among all fields of study in Austria (56% between 2010 and 2020; Statistics Austria, 2022) and Germany (50% between 2016 and 2020; Heublein et al., 2022). Large-scale observations of gender differences in self-concept and attitudes in favour of male school students (e. g., Goldman & Penner, 2016) add a further dimension to this discrepancy between high mathematics self-concept and dropout. This calls for a closer scientific investigation of motivational beliefs of students and gender differences at the secondary-tertiary transition into STEM fields.

Challenges for beginning bachelor-level students on a formal, mathematical level have been studied extensively (e. g., Gueudet, 2008; Thomas et al., 2015). Less is known about what effects these challenges bear on students' motivational beliefs and about suitable ways of supporting students so their beliefs develop favourably. Di Martino et al. (2022) concluded from a qualitative transnational study that a high mathematical self-concept in secondary school is not necessarily maintained at university. Moreover, they found that a high mathematical self-concept at the end of upper secondary

school is characteristic of students who enrol in STEM field programs, while a low mathematical self-concept at university fuels students' dropout intention. The mathematical self-concept of students thus plays a decisive role both for their intention to enrol in and decision to remain in an undergraduate STEM field program. In the context of both primary and secondary education, Wigfield and Eccles (2000) summarize the findings of several of their studies, showing that motivational beliefs have a significant impact on the choices made by students and – ultimately – on their performance, effort, and persistence as well. They based their investigations on the *expectancy-value theory* of achievement motivation (Eccles et al., 1983). Much research in education has been based on this theory. For example, Lazarides et al. (2022) created motivational profiles of grade 9 students and found a general decrease in motivation by the time they reached grade 10. Schweder and Raufelder (2022) observed positive effects of self-directed learning in grade 6 to grade 9 classrooms. Notably, gender differences in favour of male students were revealed, extending findings in the context of primary schools (e. g., Oppermann et al., 2021) and upper secondary schools (e. g., Watt et al., 2019). Gender differences in various expectancy beliefs have been observed among school students of all ages (Pajares, 2004). Giberti (2019) pointed to gender differences in task-specific mathematical self-efficacy and general mathematical self-concept detected by transnational surveys at the primary and secondary school level; these differences were reduced when controlled for school grades.

In the review of Huang (2013), gender differences in mathematics self-efficacy were found to be higher at college level than at any prior educational stage. The scientific literature is lacking studies on how student motivation develops during the secondary-tertiary transition and whether changes in motivation are gender-specific. Therefore, in this work, we pose the following research question:

What gender differences, if any, are there in the development of students' achievement motivation as measured by expectancy-value theory during the secondary-tertiary transition into STEM fields?

We report general developments and point out differences with regard to gender where they arise.

## Theory

Eccles et al. (1983) have established the *expectancy-value theory* of achievement motivation, asserting its close relation to how tasks are chosen and to what degree of persistence and ultimately success tasks are pursued. This theory incorporates beliefs in both its two dimensions *expectancy for success* (*expectancy beliefs*) and *task values* (*value beliefs*). Expectancy for success is the students' "perceived ability to succeed on a task", task values are the "reasons [of students] for engaging in a task" (Gaspard et al., 2015). Eccles et al. (1983) have further divided value beliefs into *attainment value* ("importance of doing well on a given task"), *intrinsic value* ("enjoyment one gains from doing the task"), *utility value* ("how a task fits into an individual's future plans"), and *cost* ("how the decision to engage in one activity [...] limits access to other activities"). While utility value is related to extrinsic motivation, attainment value and intrinsic value are associated with intrinsic motivation (Gaspard et al., 2015). In line with, for example, Lazarides et al. (2022), we examine expectancy beliefs in terms of self-efficacy.

Based on the observation that students tend to have a high mathematics self-concept when entering university (Di Martino et al., 2022), on the one hand, and on the high dropout rates in STEM fields, on the other hand, we hypothesize that both expectancy beliefs and value beliefs of beginning students

decrease in the course of the initial stage of their degree programs. We also hypothesize that the developments are in favour of male students when compared to female students.

## Methods

We established a repeated-measures questionnaire study capturing expectancy and value beliefs of beginning students of the Vienna University of Technology, Austria, in the winter term 2022/23. Based on the well-established scales of Gaspard et al. (2021), we developed a questionnaire consisting of the subscales *general utility* and *utility for job* to measure utility value, the subscale *intrinsic value* to measure intrinsic value, the subscales *importance of achievement* and *personal importance* to measure attainment value, and the subscales *effort required*, *emotional cost*, and *opportunity cost* to measure cost (see Table 1). To measure expectancy values, a reduced version (three out of four original items) of the subscale *self-efficacy* was used. The selection of scales was based on the consideration that, out of the 16 scales of the original questionnaire of Gaspard et al. (2021), these were the relevant scales for the specific context of our study which had proven highly reliable in a small-scale pilot study (N = 35). We used a 6-point Likert scale (1 = “do not agree”, 6 = “strongly agree”) for collecting the data. A list with all items used is provided as supplementary material (available at <https://phaidra.univie.ac.at/o:1771793>).

**Table 1: Sample items and internal consistencies of questionnaire scales**

Construct	Sample item	Number of items	McDonald's $\omega$	
			MP1	MP2
General utility	Math is very useful for me.	2	.653 <sup>a</sup>	.705 <sup>a</sup>
Utility for job	Math skills will pay off in my job later.	3	.900	.947
Intrinsic value	Math is fun.	3	.923	.931
Importance of achievement	Good grades in math are very important for me.	3	.866	.898
Personal importance	Math is important to me personally.	3	.849	.891
Effort required	Doing math is exhausting for me.	3	.851	.872
Emotional cost	Math is a real burden on me.	3	.737	.790
Opportunity cost	I have to give up many things to be good at math.	3	.827	.862
Self-efficacy	I am convinced that I can understand even the most difficult content in my degree program.	3	.858	.895

Note.  $n_{MP1}=428$ ,  $n_{MP2}=402$ .

<sup>a</sup> For assessing the reliability of the two-item scale, the Spearman-Brown coefficient was calculated instead of McDonald's  $\omega$ .

The questionnaire was administered to the students at the beginning of the mathematics bridging course in September 2022 (measurement point 1 = MP1) and about two months into the semester in November 2022 (MP2). We considered the bridging course a suitable opportunity to ask incoming students to participate in MP1 since the great majority of the beginning students at that university attend this course. The students were given time to fill in the questionnaire on site. This way, we aimed to reach a broad sample. The administration of the questionnaire before the start of classes should have helped ensure that answers given at MP1 capture experiences at school. For most incoming bachelor level students at that university, the bridging course is the first time where they are immersed in the university environment and experience a style of teaching mathematics that is markedly different from school. According to the course description<sup>1</sup>, the aim of the bridging course is to review mathematical competencies taught at school and to strengthen operational skills to the level expected from incoming students at that university. MP2 was scheduled two months into the semester as we expected that, within this period, the students have become familiar with their new environment at university.

Our sample consists of 428 incoming students enrolled in various bachelor's degree programs in STEM fields (e. g., civil engineering, computer science, electrical engineering, mechanical engineering, technical chemistry, technical mathematics, technical physics). As shown in Table 1, the reliability of the scales used was sufficient ( $\omega > .6$ ) and for the most part very good ( $\omega > .8$ ).

## **Analysis**

To test the hypotheses, we conduct repeated-measures analyses of variance (ANOVA) between the two measurement points and contrast the developments between gender (female:  $N = 114$ ; male:  $N = 310$ ) as between-subject factor. Due to the low occurrence, we did not include participants who indicated their gender as diverse ( $N = 2$ ), preferred not to declare their gender ( $N = 2$ ).

For testing the hypothesis regarding the overall development between the two measurement points, we report the main effect of each construct over time. To examine the hypotheses regarding gender differences, we report within-subject effects as interactions of the gender variable with the development of the constructs. We use the Pearson correlation coefficient  $r$  to interpret the effect size of the developments (small:  $r = .1$ , medium:  $r = .3$ , large:  $r = .5$ ).

## **Results**

The results show that all the measured value beliefs of incoming students decrease significantly during the first weeks at university (see Table 2, column "Time"). The decrease of students' general utility value of mathematics has large effect size. Students' perception of the utility of mathematics for their future job decreases with medium effect size. While no gender differences are seen in the latter dimension of utility (see Table 2, column "Time \* Gender"), the general utility value of mathematics decreases statistically significantly stronger among female students ( $M_{MP1} = 4.46$ ;  $M_{MP2} = 3.68$ ) than among male students ( $M_{MP1} = 4.45$ ;  $M_{MP2} = 3.90$ ).

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<sup>1</sup> see <https://www.tuwien.at/studium/studieren-an-der-tuw/akmath/allgemeines> (retrieved April 26, 2023)

Intrinsic value also decreases with a large effect size; gender comparisons (see Figure 1, left) show a statistically significant difference in favour of male students ( $M_{MP1} = 4.35$ ;  $M_{MP2} = 3.94$ ) compared to female students ( $M_{MP1} = 4.48$ ;  $M_{MP2} = 3.79$ ).

**Table 2: Results of repeated-measures ANOVA with gender contrasts**

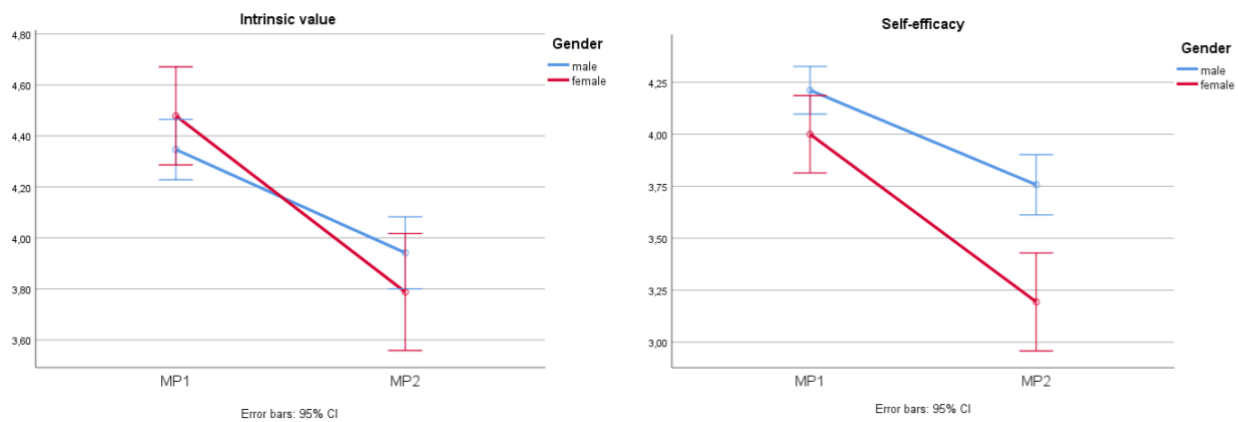
Construct	MP1	MP2	Time			Time * Gender	
	M (SD)	M (SD)	F	df <sub>R</sub>	r	F	r
General utility	4.45 (0.94)	3.84 (1.17)	132.87	401	.50***	3.89	.10*
Utility for job	5.12 (0.86)	4.64 (1.20)	57.39	401	.35***	0.02	<.01
Intrinsic value	4.39 (1.03)	3.90 (1.23)	119.18	398	.48***	7.54	.14**
Importance of achievement	4.53 (1.00)	3.95 (1.22)	114.64	399	.47***	7.97	.14**
Personal importance	4.16 (1.02)	3.80 (1.18)	54.62	401	.35***	1.27	.05
Effort required	3.21 (1.06)	4.03 (1.16)	219.97	401	.60***	1.80	.06
Emotional cost	2.25 (0.91)	2.90 (1.14)	160.42	399	.54***	2.09	.07
Opportunity cost	2.98 (1.06)	4.09 (1.14)	337.79	401	.68***	4.18	.10*
Self-efficacy	4.15 (1.00)	3.60 (1.29)	92.73	401	.43***	7.02	.13**

*Note.* M...mean value, SD...standard deviation, F...ANOVA test statistics, df<sub>R</sub>...degrees of freedom of residuals, p...significance, r...Pearson correlation coefficient; \* p < .05, \*\* p < .01, \*\*\* p < .001

The components of attainment value examined in this study also drop statistically significantly. The importance of achievement decreases within the first few weeks at university with a large effect size; the decrease in personal importance of mathematics is of medium effect size. Controlling for gender reveals that the development of the importance of achievement among the male students ( $M_{MP1} = 4.47$ ;  $M_{MP2} = 3.98$ ) is again statistically significantly better than among the female students ( $M_{MP1} = 4.70$ ;  $M_{MP2} = 3.86$ ).

All three aspects of cost increase with very high effect sizes. A statistically significant difference is found in opportunity cost where cost increases stronger among female students ( $M_{MP1} = 2.89$ ,  $M_{MP2} = 4.19$ ) than among male students ( $M_{MP1} = 3.01$ ,  $M_{MP2} = 4.05$ ).

The pattern observed in the value beliefs is also found in the expectancy component. The decrease in self-efficacy is of medium to large effect size. The comparison between genders shown in Figure 1 (right) is in favour of male students, whose self-efficacy decreases statistically significantly less ( $M_{MP1} = 4.21$ ,  $M_{MP2} = 3.75$ ) than the self-efficacy of female students ( $M_{MP1} = 4.00$ ,  $M_{MP2} = 3.19$ ).



**Figure 1: Gender differences in the development of intrinsic value (left) and self-efficacy (right)**

## Discussion

This study investigates the development of beginning students' expectancy of success in mathematics and their value beliefs about mathematics. The findings show a striking decrease of value and expectancy beliefs within a few weeks at university. This trend is seen in all aspects measured. This suggests, on the one hand, that the general downward trend in achievement motivation seen at school continues at the higher education level, even if beginning students mostly represent a highly positively selected subgroup of students regarding their achievement motivation in mathematics. This selection of motivated students might, at the same time, be a reason why such strong decreases occur: While the students had been used to being successful and among the top performing students in mathematics at their respective schools, they base their self-assessment on comparison with a new peer group who, other than at school, exhibit a relatively high self-concept as well as competence in mathematics (see also Di Martino et al., 2022).

Notably, the results consistently show increases in the standard deviations of the constructs over the first weeks at university, suggesting that expectancy of success and value beliefs of students are less uniform after a few weeks at university than they were at the beginning. This, in turn, indicates that the development of a substantial subgroup of students might not follow the general trend and be able to keep up a high level of expectancy and value beliefs. This finding calls for investigations of subgroups in further research, possibly by carrying on the person-centred approaches employed by Lazarides et al. (2022) and Schweder and Raufelder (2022) at the level of secondary education to the context of higher education. To further discern the trend in expectancy and value beliefs, replicating the study with a third measurement point could substantiate the results of this study.

We should note that the schooling of the great majority of participants in our study was affected by the COVID-19 pandemic, which might have weakened the stability of students' self-concept and limit the validity of our findings to this specific setting. In this context, we note that during the period of distance learning in Austria female students reported higher intrinsic value than male students (Korlat et al., 2021). However, the study of Korlat et al. (2021) is not specific to the context of mathematics.

A substantial proportion of the participants of MP1 could not be reached at MP2. A check for selection effects shows that students who participated only at MP1 ( $N = 282$ ) had statistically significantly ( $p < .05$ ) less favourable value beliefs than those who participated at both measurement points ( $N = 428$ ); no statistically significant difference is seen in self-efficacy. Except for importance

of achievement, the beliefs of students who participated only at MP2 (N = 75) did not differ statistically significantly from those who participated at both measurement points. The fact that the students who could not be reached after MP1 held less favourable self-beliefs suggests that unfavourable self-beliefs are related to early dropout. Other reasons could be a lack of information or of motivation to participate in the study.

Despite efforts towards gender equity in STEM fields, the results of our study suggest that male students' value beliefs and expectancy beliefs develop more favourably at the secondary-tertiary transition than those of female students. Even though no statistically significant difference could be found in four of the investigated aspects, five aspects did show a difference – all in favour of male students. This suggests that gender differences in favour of male students seen in schools (e. g., Lazarides et al., 2022; Oppermann et al., 2021; Watt et al., 2019) continue in tertiary education and thus need to be addressed by research institutions. Regarding self-efficacy, the gender bias reported in the large-scale review of Huang (2013) was replicated in our study at a single institution. Self-efficacy as well as those value aspects that are related to intrinsic motivation showed the differences with the largest effect sizes. According to Jerusalem and Mittag (1995), these aspects are all indicative of confidence and persistence in the face of challenges, and thus of particular importance for a successful secondary-tertiary transition.

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